Space Weather Technical Forecast

Issued on Thursday, 15 September 2022 at 13:14 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: CME arrived, Chance G1 in immediate term, probably then sustained by arriving fast wind. R1/R2 Likely, but risk falling later in weekend. Active electron fluence soon moderating.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity was Low in the past 24 hours, but notably with an M1.1 flare shortly preceding the period observed from AR3098 at 14/1018UTC. The largest flare of the current reporting window was an impulsive C7.7 observed from AR3098 at 14/1216UTC. Analysis of this group is starting to be compromised by limb foreshortening effects, however it appears to be areally shrinking and manifests as an Ehc/Beta-Gamma, with mobile intermediate spots that appeared to become fewer in number.

Also of note in terms of flares was a long-period northwestern limb C6.3 observed at 15/0633UTC, probably from Ex-3101. This is considered likely to be the progenitor of a Coronal Mass Ejection (CME), however coronagraph imagery is not yet available to confirm this, and in any case any Earth trajectory is considered relatively unlikely from such a position on the disc.

In total there were up to four sunspot regions on the solar disc. In addition to the aforementioned large and complex AR3098, there were two other spots with potential large spans: AR3100 near centre-disc (with speculative inclusion of a diffuse trailing collection of spots to give Eso/Beta); and also AR3012 in the southeast, which appears as a Dso/Beta, possibly trending towards an Eso/Beta. Finally, there was a diffuse unipolar collection of spots that was seen to develop in the southeastern quadrant over the period, but only attaining Axx/Alpha classification, and yet to be numbered.

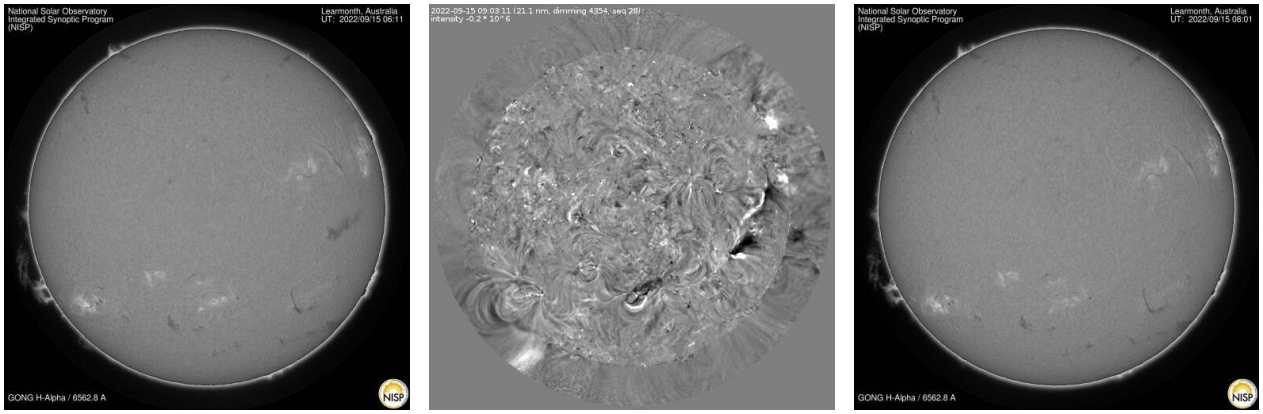


Figure 0: NSO GONG H-alpha imagery from Learmonth observatory either side of a SIDC ROB processed time-integrated dimming in AIA 211, all showing a disappearing filament west of centre disc. This event is being monitored for in coronagraphs.

A broad but slow filament was seen to disappear in the west central disc on Learmonth H-alpha

© Crown Copyright 2022. All Rights Reserved.

imagery around 15/0730UTC. This event does not yet appear in coronagraph imagery - should it have even left the immediate solar environment. No new Earth-directed CMEs have been observed on available imagery, although the previously mentioned northwest limb event is awaited.

Solar Wind / Geomagnetic Activity: The solar wind trace, as measured by DSCOVR and ACE at L1, was initially symptomatic of possible very minor transient contamination or a slow regime, but notably interrupted by the arrival of a stronger and more definite CME at L1 during the UTC evening and overnight period.

The initial perturbations were relatively blunted, but the solar wind started to change in earnest from about 14/1900UTC in the possible shock, with the sharpest gradients in solar wind measures observed at 14/2150UTC with the advent of a magnetic cloud-like signature. There was no single sudden impulse of sufficient scale to warrant an alert recorded at BGS magnetometers in the period, however the Hartland H-component did approach changes of approximately 30nT at times (three occasions) in reaction to the CME.

For discussion as to possible causes of the above, please see the Geomagnetic Activity section.

The solar wind speed started the period at Background levels on a slow decline through 300km/s before undergoing a slight increase to 350km/s with the arrival of the magnetic cloud after 14/2150UTC. The solar wind density showed a concurrent peak, reaching 60ppcc before a precipitous drop into near-single figures thereafter. The IMF was mostly small-scale but turbulent prior to the main CME signature, with a variation between 2 and 12nT, before a sharp increase to a much more stable 16nT in the wake of the cloud. The north-south component of the magnetic field came in anti-aligned with Earth's field in the immediate commencement of the cloud signature, with -14nT briefly recorded, before a rapid switch to a peak of +14nT. The phi angle was mainly positive (away from the Sun), but flitting to negative for brief periods around 14/1400UTC and 14/2100UTC.

The net result of the above solar wind measures was provisionally two successive peaks of Kp '4o' in the 21-24UTC and 00-03UTC intervals, i.e. the three-hour intervals containing the CME front and its immediate aftermath. This was obviously heavily moderated by the favourable Bz component.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) as measured at GOES-16, has been slightly elevated throughout, with a slight downward trend from a peak near 2.5pfu.

Electron flux was High initially, reaching 1.58e4 pfu at 14/1640UTC, but has since declined to Normal Background levels due to geomagnetic activity. The corresponding 24-hour electron fluence remained above the Active threshold, (1e8 integrated pfu), with a 15/0001UTC observed value of 3.59e8 integrated pfu, but with a sharp downward tendency thereafter.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate activity is Likely until day three, with a step-wise reduction through day three (Sunday 17 September) as a result of AR3098 leaving the Earth-facing disc. No notable regions are due over the limb to compensate, and Likely M-class flares become a Chance by the end of the period.

Solar Wind / Geomagnetic Activity: The (probable) only CME in the forecast has arrived and its effects are ongoing. A drift into a more-sustained anti-aligned portion of the cloud may occur in the immediate term, giving a Chance of G1 to end day one and at least the first part of Friday 16 September, day two.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

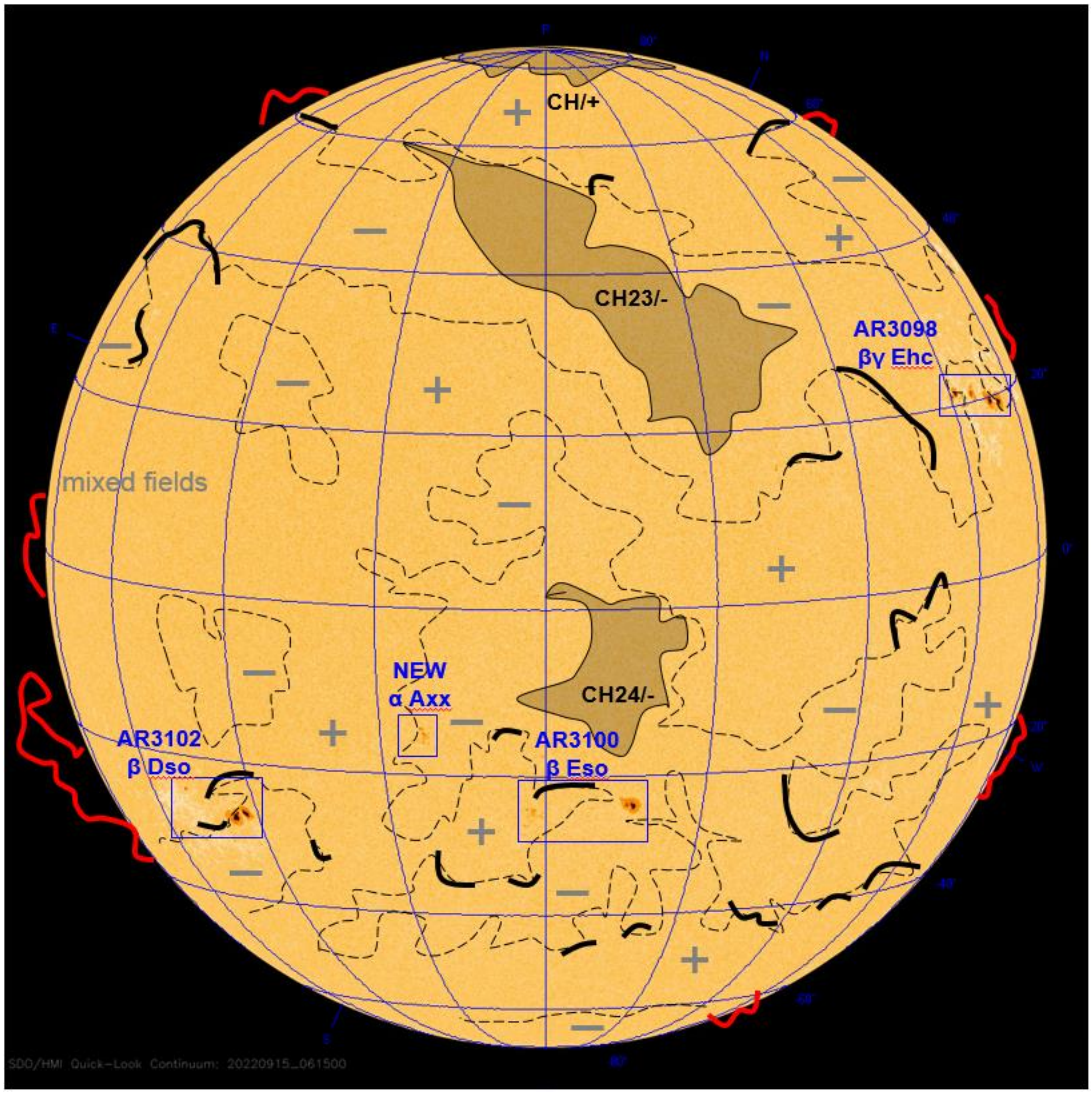
© Crown Copyright 2022. All Rights Reserved.

The fast wind from coronal hole 23 should then follow later on day two, giving a resurgent Chance of G1 partitioned between this and the following UTC day, before finally abating to Quiet through day four, Sunday 18 September.

Energetic Particles / Solar Radiation: There is a daily Slight Chance of S1 - mainly the result of AR3098 moving through its most geoeffective solar longitudes in the period - a risk should it flare appropriately. This risk is coupled with the current higher-than-typical baseline level of activity.

The high energy electron flux (greater than 2MeV) is expected to start at mainly Normal Background levels in the wake of the current CME, probably not recovering to High until after the CH23 fast wind, with this possible on day three, Saturday 17 September. Active electron fluence should soon fall sharply, Likely eventually recovering into day four, Sunday 18 September.

Figure 1. Solar Analysis Valid 15/0615UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

Geomagnetic Storms:

As discussed in the Solar Wind/Geomagnetic Activity section, Earth has seen the arrival of a CME in the reporting period.

While conjectural, there is a possibility that this is the awaited faint partial halo CME emitted on 09 September. This had no obvious source region when observed, but was inferred from coronagraphs at 232km/s with a postulated arrival time of 15/0001UTC - i.e. it has arrived two hours early. Perhaps supporting this hypothesis is the unusually slow subsequent solar wind speed at L1 - barely changed from prior to the arrival in the low-300s of km/s, although the CME analysis itself is on the lower limit of physicality to escape the Sun at all. The apparent precision of this estimate belies large error bars given uncertainties in the analysis (not least by being unable to confirm a source). It is also accepted that other minor transients may be responsible.

Should the above not be the cause, there is also the possibility that this is the arrival from a more obvious filament lift off from the west centre disc on Sunday 11 September, although this event barely registered on coronagraph imagery, severely hampering analysis (in many ways the opposite problem).

Whatever the cause, the negative Bz portion of the cloud is felt unlikely to be finished, and a gradual drift into this sector is expected over the coming 12-18 hours or so. This will probably prolong the risk of G1 over this period, especially during the UTC evening and perhaps the early hours before finally abating into daybreak of day two, Friday 16 September.

Figure 2: Suggested IMF and Bz evolution in the coming hours – likely to be more impactful than the Kp and Kgbi indices of 1 seen at present.

There should then be something of a lull before the onset of the only coronal hole fast wind of the forecast. The high speed stream from coronal hole 23 is due to connect with Earth later on 16 September. This feature is of negative polarity and the Earth is close to the autumnal equinox, however its predecessor did give an isolated G1 interval on last pass, where it achieved 650-700km/s and a two-day duration. This should again offer a Chance of G1, with this risk partitioned between days two and three of the period Friday 16 and Saturday 17 September, greatly reducing into day four as speeds wane.

All considered, there is a Chance of G1 later on day one due to a possible period of negative Bz from the currently geoeffective CME magnetic cloud. A lull should then ensue on day two, before possible CH23/- fast winds later and on into Saturday 17 September, probably waning by the end of the four days to largely Quiet conditions once again.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

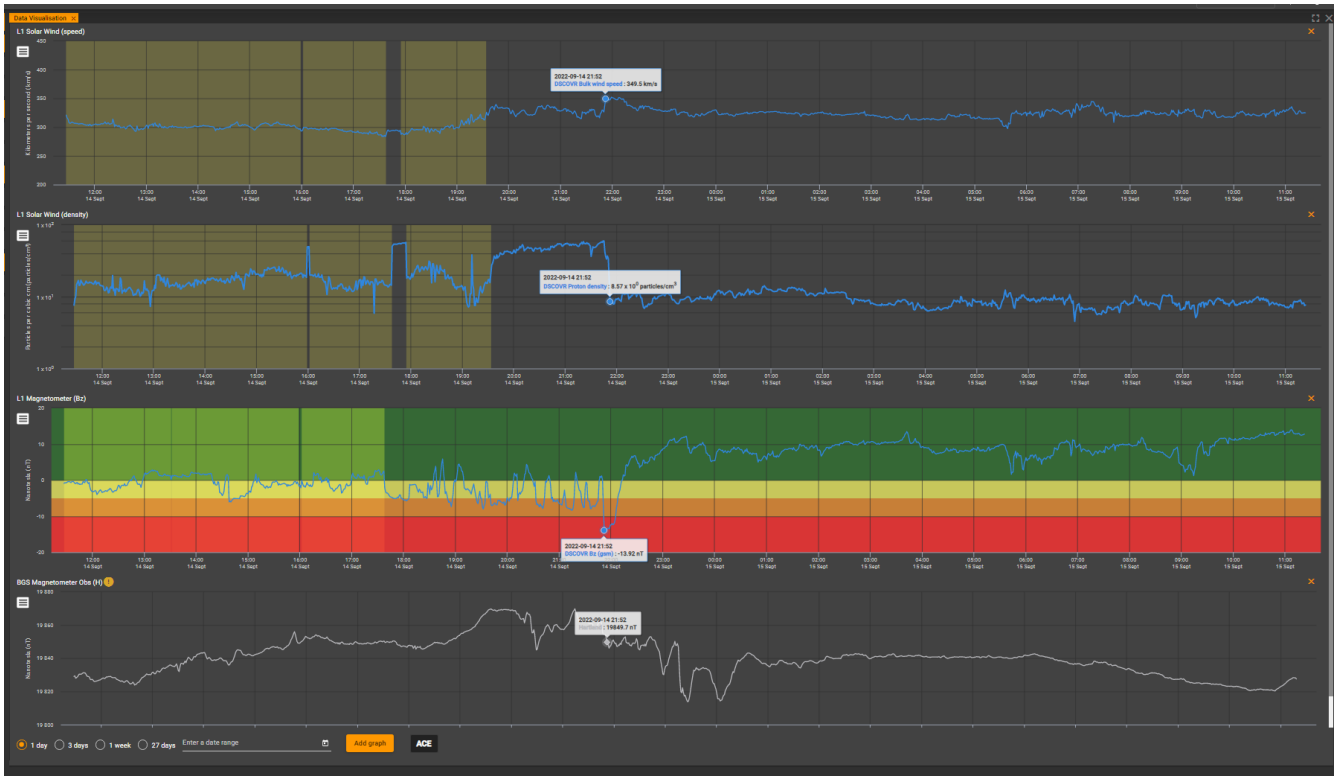
© Crown Copyright 2022. All Rights Reserved.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	40	40	30	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Most likely nil, small chance of possible 11 September west centre disc filament CME still en route.

Figure 3: MOSWOC visualisation of L1 solar wind speed at DSCOVR and ACE (top plot, with ACE in yellow shading); density; and Bz component. Also shown is BGS's Hartland magentometer, with deflections generally of around 30nT at peak. The main magnetic cloud-like signature can be seen to be nascent from 14/2150UTC, with Bz forecast to possibly decline into negative territory later today.



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

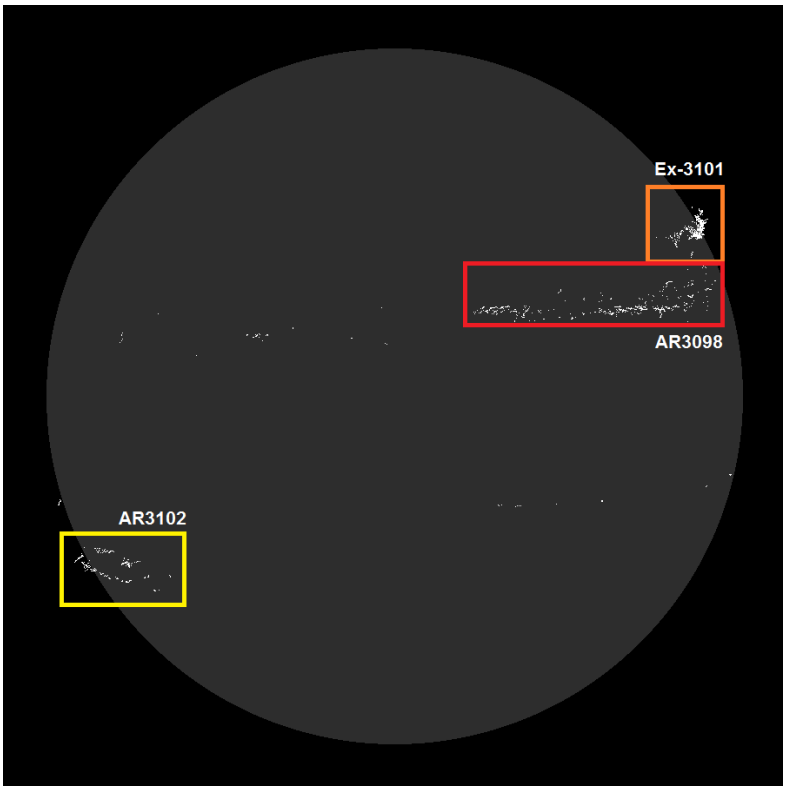
Radio Blackouts - X-Ray Flares:

There are up to four sunspot regions on the visible disc at present. Activity remains dominated by the largest and most complex region on the disc, AR3098 in the northwestern quadrant. This group is due to leave the Earth-facing side through day three, Sunday 17 September, with the simpler regions AR3100 and AR3102 then taking up the mantle, albeit to a lesser degree due to their lower levels of complexity and lack of recent evidence of activity.

Despite returning Carrington longitudes of Ex-3086 (for example) before the end of the current working week UTC, there does not appear to be evidence of significant surviving regions in this location, and the trend in flare risk is therefore downwards: from Likely M-class to a Chance over the four days.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**R1-R2 M Class**	No	60	60	40	25
Very Active	**R3 to R5 X Class**	No	5	5	5	1

Figure 4: SIDC ROB processed X-ray flare locations in the past seven days (C-class and above). Almost all the activity is split between just three spot groups, with only two currently on the front side.



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10MeV) remains slightly elevated, but sub-S1.

The cause of the current enhancement is not certain, perhaps being related to unseen far-side activity (perhaps evidenced by the soft spectral rise), however the main risk from the current crop of front-sided sunspots remains from AR3098. This group is expected to transit the best-connecting longitudes of the Sun in the four days should it flare appropriately, with a corresponding daily 15% Slight Chance throughout, in part also due to the higher baseline at present.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	≥ S1	No	15	15	15	15
Very Active	≥ S3 *	No	1	1	1	1

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

Figure 5: Top: the past week in GOES16 greater than 10MeV proton flux (blue trace), showing occasional sub-S1 level enhancements. Also shown (below) is GOES16 X-ray flux, with no strong potentially causative correlation seen between the two plots, perhaps suggesting far side activity is at least in part responsible (also perhaps hinted at by the gradual proton level rises).

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

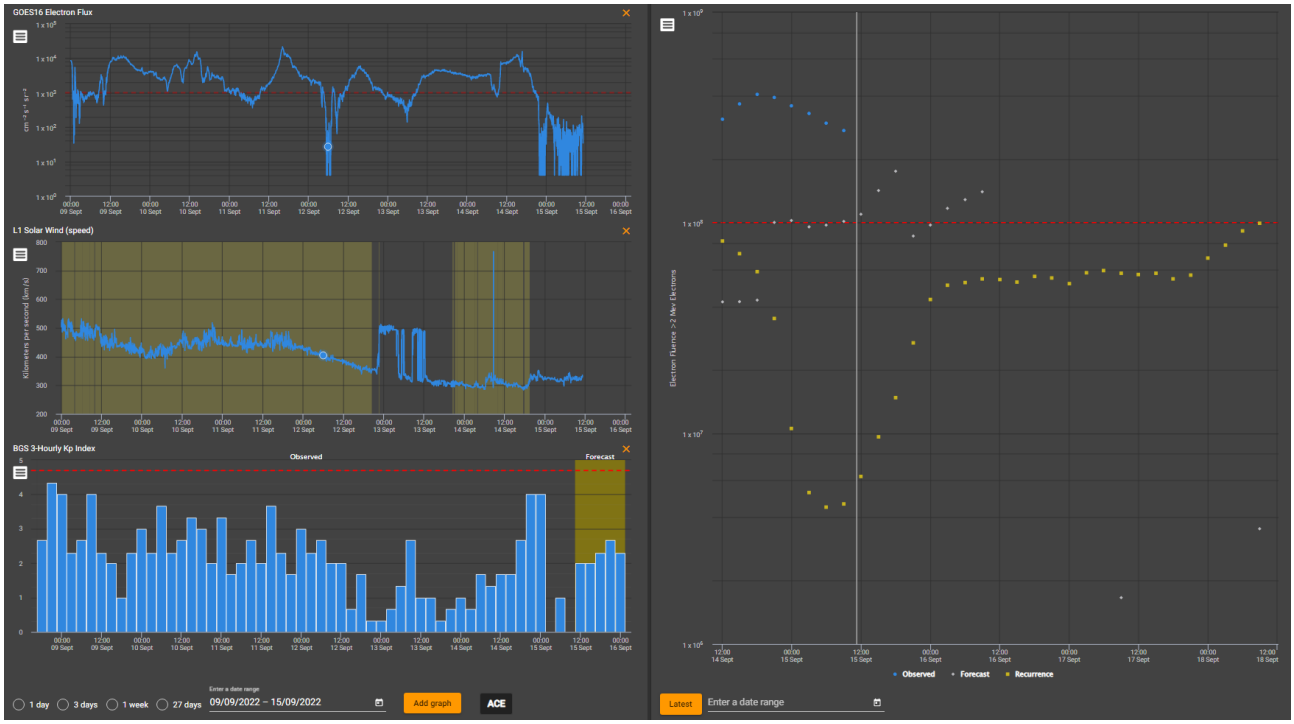
High Energy Electrons Event (≥ 2MeV):

High energy electron flux showed a significant fall from High to Normal Background counts at GEO in the past 24 hours. This may well be the death knell of the recent protracted Active fluence - ongoing since the high speed stream of coronal hole 20, with the solar wind environment in the immediate wake of the current CME probably not supportive of high electron flux.

The forecast beyond this should show a recovery however, in an eventual response to the following fast wind from CH23/-, with Active fluence narrowly attained on the previous rotation. Initial Active fluence should soon fall below threshold, remaining so until after the onset of CH23's fast wind, whereupon Active fluence should again become Likely once initial geomagnetism fades.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	Yes	100	20	40	60
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 6: Top left: Past week in GOES16 greater than 2MeV electron flux, showing lasting response to L1 solar wind (middle plot) measured by DSCOVR and ACE (the latter with yellow shading). Also shown is BGS Kp geomagnetic activity, with the drop in electron flux tied to the Kp 4o intervals in the past 24 hours. Shown on the right is the latest fluence observation and MOSWOC REFM, with 27-day fleunce persistence in yellow dots indicating the chance of similar on this rotation later this weekend, even if REFM perhaps thinks otherwise (white dots).



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.